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ABSTRACT

A warm and sunny subtropical climate helps make Hawaii an important sugar producer. History records that sugarcane was already present when Captain James Cook discovered the islands in 1778, and that the first successful sugarcane plantation was started in 1835 by Ladd and Company at Koloa. The first recorded export of Hawaiian sugar was in 1837, when two tons were exported with a value of $200. Problems faced by early sugar planters were many and included shortages of labor, water, and money. The ingenuity of the early sugar planters in solving these problems was a factor in their long-range success. They imported Chinese immigrants to work in the fields, were innovative in their acceptance of new machinery, began to irrigate, and formed an organization, the Planters' Labor and Supply Company, for their mutual aid and support. Currently the Hawaiian Sugar Planters' Association runs an experiment station that is known throughout the world for its research in many scientific disciplines. This booklet concludes by describing the sugarcane plant, the harvesting process and machinery, and what happens when sugar arrives at the raw sugar factory. The text incorporates photographs and illustrations and could be used in secondary level state history and geography courses. (RM)

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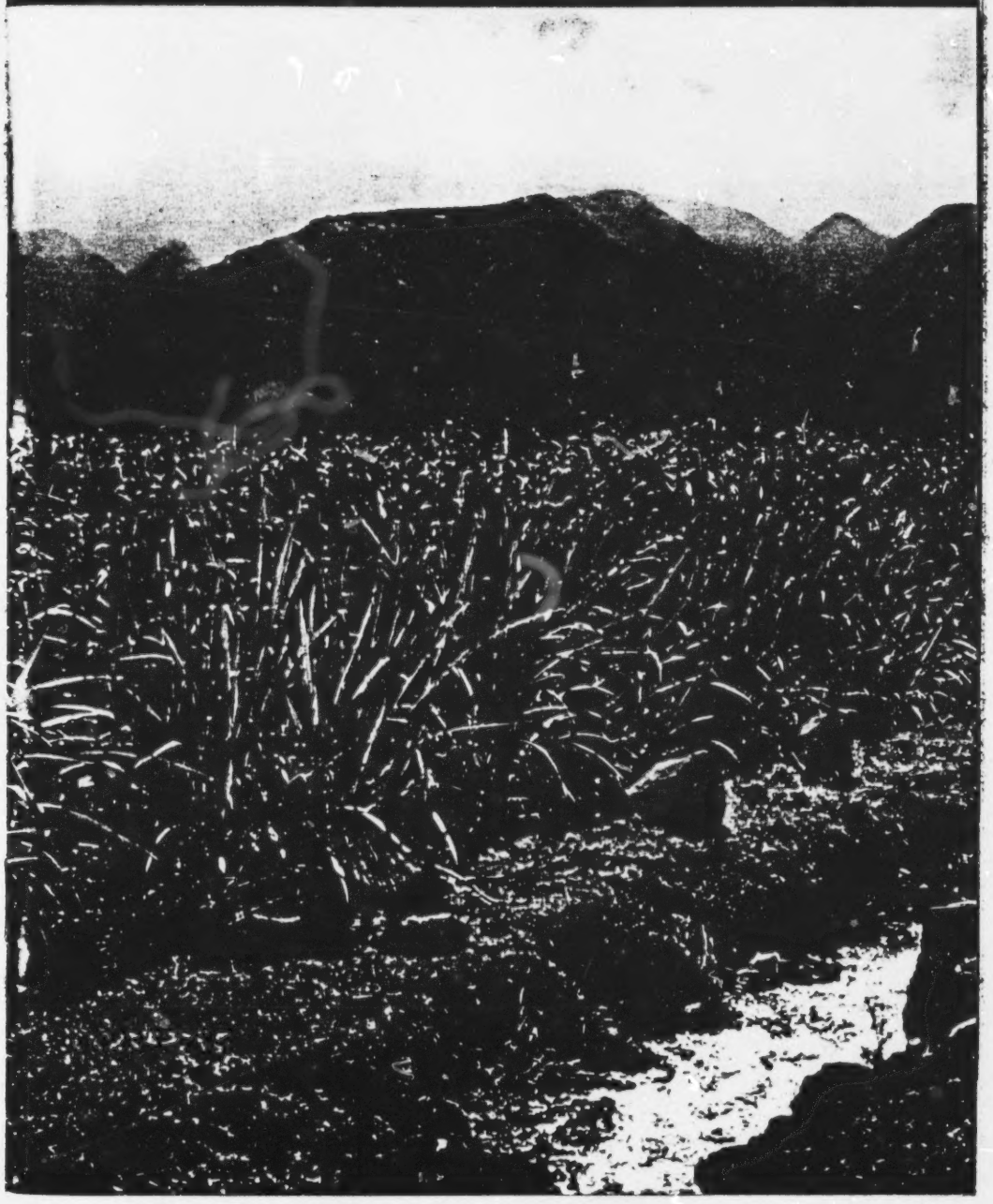
HAWAII'S SUGAR ISLANDS



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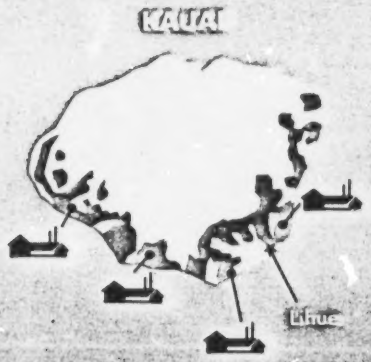

A warm and sunny subtropical climate

and an adequate water supply are natural resources which help make the State of Hawaii an important producer of sugar.

Fourteen plantations and about 550 independent sugar growers in Hawaii use about 89,000 hectares (220,000 acres) of land for growing sugarcane and they produce about 1,000,000 tonnes (1,100,000 tons) of raw sugar each year. Most of this raw sugar is sent to the Continental United States where it is refined and sold, primarily in the western and mid-western states.

Hawaii supplies about one-tenth of the sugar used by the 215 million people in the United States.

The Hawaiian Island chain stretches for 620 km (385 mi.) from southeast to northwest in the Pacific Ocean. The islands lie about 3,800 km (2,400 mi.) southwest of Los Angeles. Of the many islands in this chain, sugarcane is grown only on the four largest. The "sugar" islands of Hawaii are Kauai with a total area of 1,432 square kilometers (553 sq. mi.); Oahu with 1,575 square kilometers (608 sq. mi.); Maui with 1,890 square kilometers (729 sq. mi.); and Hawaii with 10,500 square kilometers (4,038 sq. mi.).

Scientists believe the Hawaiian chain of islands began to form some 17 to 18 million years ago when fiery lava began seeping through a fault in the earth's surface in the middle of what is now the Pacific Ocean.

Even as the volcanoes were creating the islands, a process continuing to this day, the forces of

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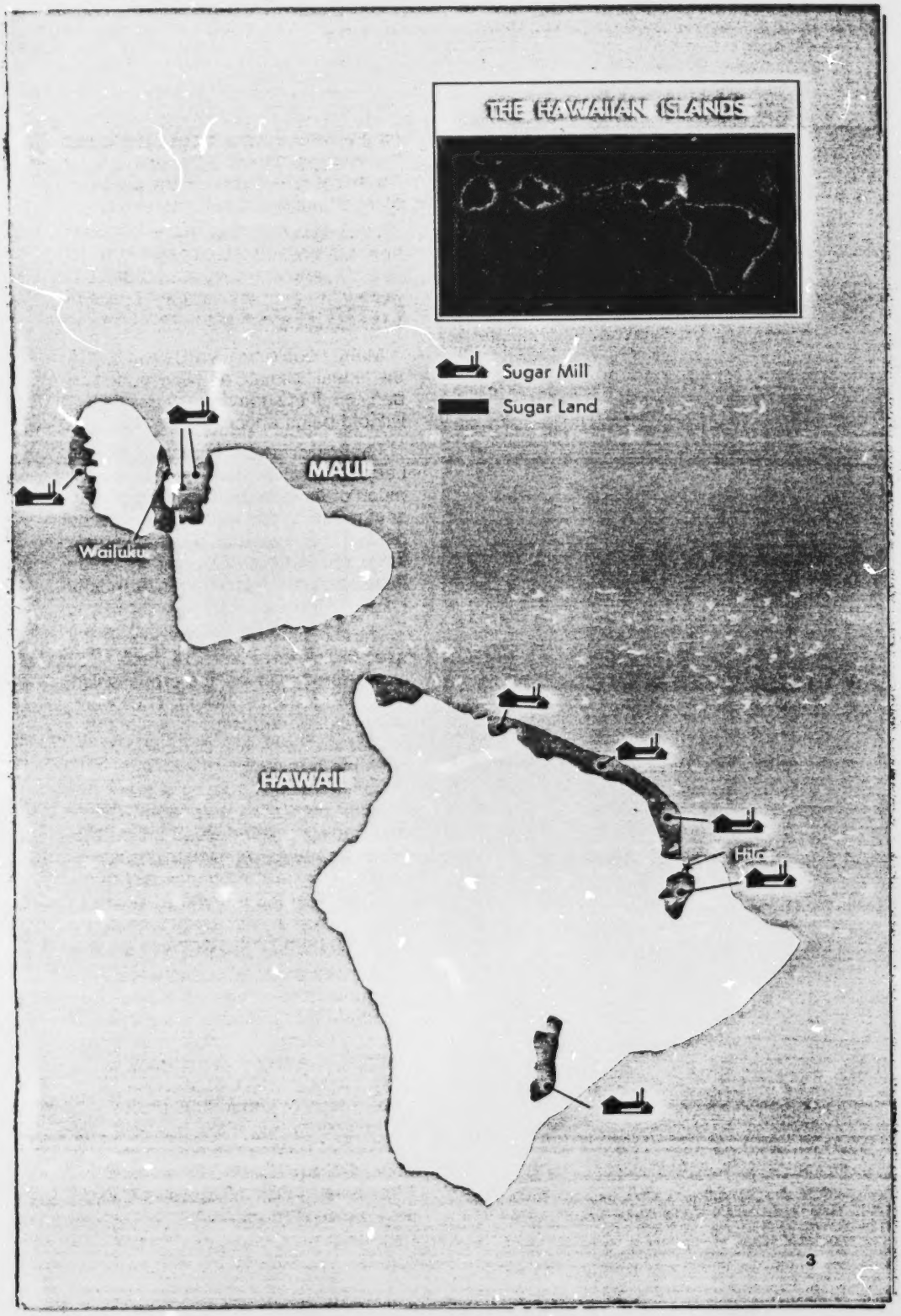
THE HAWAIIAN ISLANDS
Sugar Mill
Sugar Land
MAUI
Wailuku
HAWAII
Hilo
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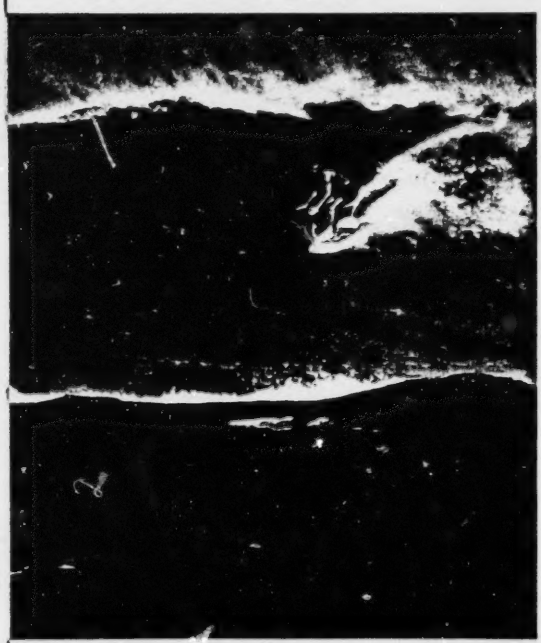
Volcano eruptions still occur on the "Big" Island of Hawaii. (Hawaii Visitors Bureau photo)



Winter brings high waves to the north shores of the Hawaiian Islands. (Camera Hawaii Photo)

nature were already beginning to turn the volcanic deposits into soil. Abundant rain hastened the process of weathering and soil formation.

Hawaii's soil has all been formed from the ancient lava flows.

Climate

Many people believe Hawaii has the "ideal" climate all year round because it is sunny and warm without being uncomfortably hot.

The Hawaiian Islands are in a tradewind zone where winds blow much of the time from northeast to southwest. These tradewinds, which pick up moisture as they travel over the ocean, hit their first land in thousands of miles when they reach Hawaii.

The moisture-laden air cools as it rises to flow over land and the moisture condenses into drops which fall as tradewind showers. Thus the windward, northeastern sides of the islands are generally cloudier and have more rain than the leeward sides. Sometimes, during winter months, the tradewind pattern is replaced for a few days at a time by winds from the southwest. These "Kona" storms can bring heavy rain to all parts of the islands. As much as 120 cm (4 ft.) of rain has been recorded from such storms.

The vast areas of ocean water surrounding the Hawaiian Islands moderate air temperature and there is comparatively little difference from summer to winter and from day to night. Summer days at sea level have a high of about 30°C (86°F) with nights having a low of about 24°C (75°F). Winter temperatures are about 3°C to 5°C (5°-9°F) lower. Mountains, which influence rainfall, also cause differences in

temperature. Each 365-meter (1,200-ft.) increase in elevation above sea level results in about a 2°C (3.6°F) drop in average temperature. Hawaii's two mountain peaks that tower more than 4,200 meters (13,700 ft.) above the ocean, Mauna Kea and Mauna Loa, frequently are covered with snow in winter months.

History

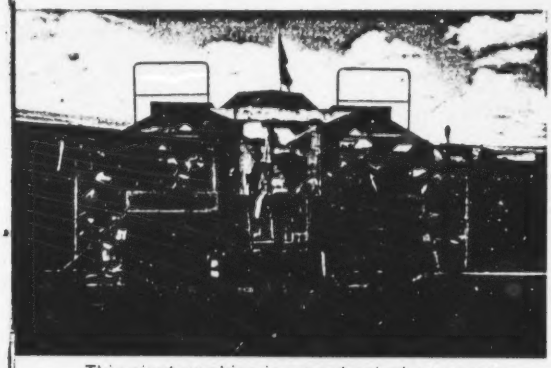
Sugarcane was already present when Captain James Cook discovered the Hawaiian Islands in 1778. His journal notes that, even before landing, ". . . we could observe several plantations of plantains and sugar-canes . . ." After going ashore on Kauai, Cook recorded, ". . . spots of sugar-canes, or plantains, . . . are planted generally as a square or oblong . . ." Anthropologists believe the Polynesians brought sugarcane, along with other food plants, when they voyaged to Hawaii from other islands to the south, probably about 1000 years ago. Hawaiian and other South Pacific people did not make sugar as we know it; they simply chewed the sweet stalks.

The first recorded planting of sugarcane in Hawaii for the purpose of extracting sugar was in Manoa Valley on Oahu in 1825. The plantation failed two years later.

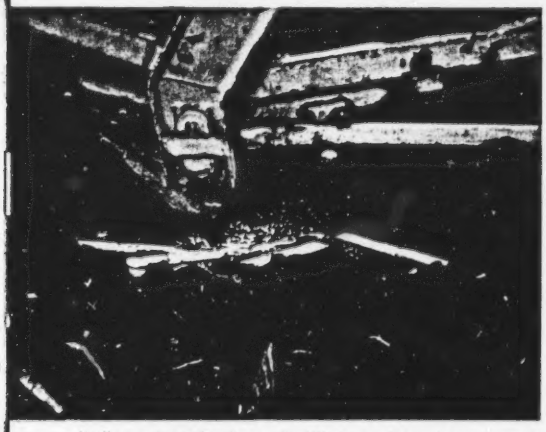
The first successful sugarcane plantation was started in 1835 by Ladd and Company at Koloa, Kauai. Some of those lands have grown sugarcane continuously to this day and are still highly productive. The area is now part of the McBryde Sugar Company.

When the first small sugarcane plantations began to prosper, other businessmen became interested in

Green field of sugarcane with clouds hovering high over the mountains is a year-round sight in Hawaii.



This giant machine is a mechanical sugarcane planter.



It digs a trench, drops fertilizer and seed cane, and then covers the trench.

sugar as an exportable product to bring in income for the Kingdom's economy. The first recorded export of Hawaiian sugar was in 1837, when two tons were exported with a value of $200.

Sugarcane plantings increased rapidly from the first 20 hectares (50 acres) on Kauai in 1835, to 40,400 hectares (100,000 acres) in 1900 and 89,000 hectares (220,000 acres) today.

As the early sugar planters became more involved in the production of sugar, they recognized that they faced mutual problems on all four sugar islands of Hawaii where they were growing, harvesting, and milling their crops.

Problems

LABOR—A major problem was the shortage of workers to plant, cultivate, and harvest the sugarcane. The native Hawaiian people were not accustomed to working long hours for someone else.

And, the population of native Hawaiians dropped rapidly after the arrival of the foreigners because the Hawaiians were not immune to the diseases brought to the islands by the new settlers and the visiting sailors.

The early sugar planters quickly determined that the local population was not sufficient to do the work needed in the sugar fields. The planters also realized that if the Hawaiian Islands were to prosper and grow, new sources of labor from other lands would be needed.

WATER—Sugarcane is a thirsty crop and each hectare of sugarcane uses about 47 million liters (5 million gal. per acre) of water during a two-year growing cycle. It takes two tonnes (2,000 kilograms) of water to produce one kilogram of sugar (2,000 pounds of water per pound of sugar).

Although the climate is generally fair and warm, there are great differences in the amount of water available in different areas within the State.

In order to grow sugarcane efficiently, the sugar planters had to find water in dry areas or they had to devise ways to transport water from the wetter areas.

MONEY—The early sugar planters were almost always in need of money to finance their operations. They also needed marketing agents to sell their sugar, purchasing agents to buy needed materials and supplies for the isolated plantations, and business agents to handle their affairs in the City of Honolulu.

Solutions

The ingenuity of the early sugar planters was a factor in their long-range success.

In August 1849, one of the planters, writing to a newspaper, proposed a convention of all planters within the Hawaiian Kingdom. The result was the formation of the Royal Hawaiian Agriculture Society in 1850 to allow the farmers and planters to exchange knowledge on agriculture in the Kingdom.

The Board of Immigration of the Kingdom of Hawaii, with cooperation of Society members, imported Chinese laborers to work in the sugar fields. The first shipload of Chinese immigrants arrived in 1852.

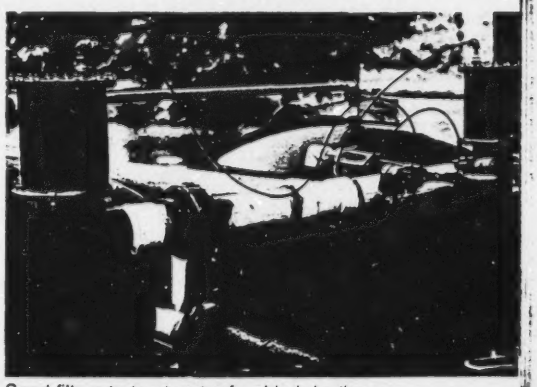
These workers set the pattern for the thousands of plantation workers who came to Hawaii in the following years from China, Japan, Puerto Rico, Portugal, the Philippines, and other areas around the world.

The early workers had been expected to work for a given number of years before returning to their home country. Many, however, found life better in Hawaii than in their homelands, and remained in Hawaii.

The multi-racial population in Hawaii today began in these early years.

Rainbows often stretch over sugarcane lands in rainy areas.

Drip irrigation tube in field of young sugarcane.



Sand filters to treat water for drip irrigation.

Fields of mature sugarcane are burned before they are harvested.

The pushrake is the harvester most commonly used in Hawaii.

MACHINERY—Hawaii's sugar planters were innovative in acceptance of new machinery and new methods of operation. The first sugar mills used crude stone rollers powered by animals. By 1838, there were two water-powered sugar mills in operation and 20 powered by horses or cattle.

The cane was cut by hand and loaded onto carts drawn by animals to be taken to the mills.

The sugarcane was crushed between crude rollers and the resulting juice was boiled in huge pans. The thick molasses was then spread in pans or on mats to dry. The result was a crude, dark-brown sugar.

In 1852, one mill began using a centrifugal to spin the liquid molasses from the sugar crystals. Mechanization of the sugar industry in Hawaii was speeded in 1853, when a steam engine was used successfully at Koloa Plantation.

Today, Hawaii has a highly mechanized sugarcane industry and virtually no hand labor is used in the planting, growing, or harvesting of sugarcane. The workers are among the highest paid full-time agricultural workers in the world.

WATER—Today, slightly over half of the sugarcane land in Hawaii is irrigated and these irrigated acres grow nearly two-thirds of the State's total sugarcane crop.

The Hawaiian sugar plantation irrigation systems are unique in that no government funds were used in their construction.

The first irrigation ditch built by the sugar industry was constructed in 1857 on Kauai. The ditch carried water from high in the mountains 18 kilometers (11 mi.) down to the drier areas below.

In 1879, the first artesian well for the sugarcane industry in Hawaii was drilled at Ewa on the island of Oahu.

In 1898, a few planters in a dry area on Maui began to ask themselves whether fresh water might be stored below ground in a manner not yet investigated. These planters reasoned that some of the

rain falling on the mountains must be filtering down through porous lava to a storage area below.

They also reasoned that this water might be stored on top of the salty ocean water which is heavier than fresh water. These planters actually discovered what is known as the "Ghyben-Herzberg Lens." This water lens was named for two German scientists who were discovering the same phenomenon at about the same time in Germany.

The discovery of the fresh water lens by the Hawaiian planters allowed them to tunnel or drill vertical shafts for pipes to skim off this available fresh water. This development has been called the single most important discovery in the continuing development of the sugar industry as well as the eventual urbanization of some parts of the Hawaiian Islands.

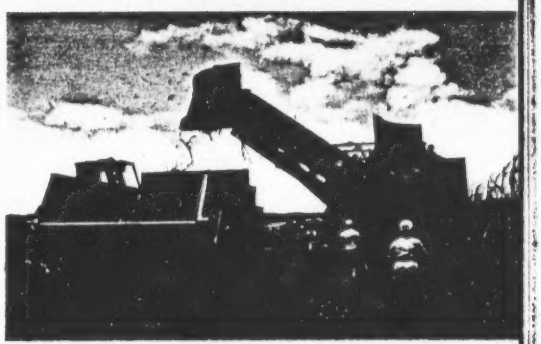
Scientists and engineers are constantly searching for better ways to use irrigation water. Some plantations irrigate by running water through furrows; others use the newest method, "drip" irrigation. In drip irrigation, water seeps out of tiny holes in plastic tubing laid along each row. Researchers have found this type of irrigation delivers water to the sugarcane plant in the most efficient manner and with the least amount of wasted water.

Organization

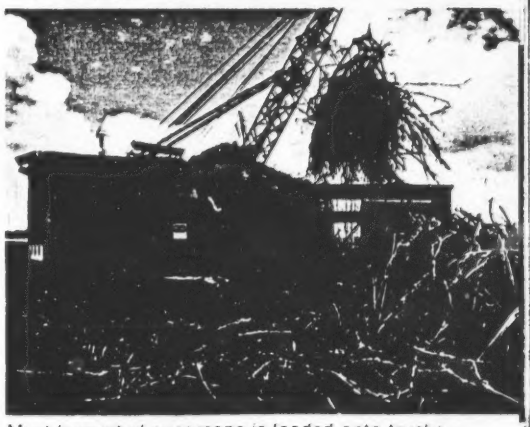
Sugarcane planters from throughout the Kingdom of Hawaii met in Honolulu on March 20, 1882, to discuss formation of an organization for their mutual aid and support.

The planters agreed to pay for an

On the Island of Hawaii many plantations use the V-cutter harvester.

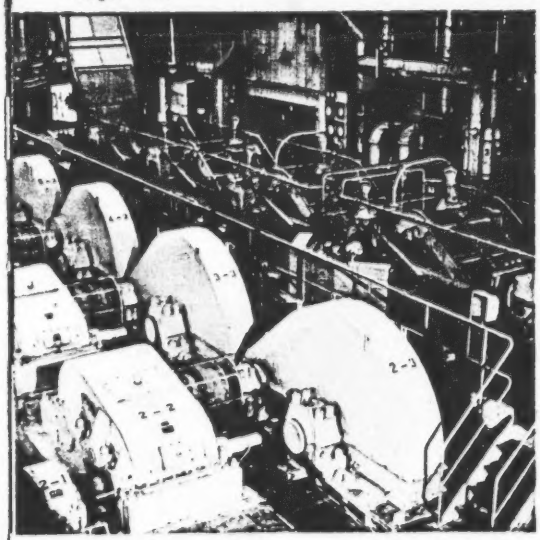


Cut-load harvester is a new machine for harvesting sugarcane.



Most harvested sugarcane is loaded onto trucks by cranes.

Cane trucks with tons of cane on the way to the sugar mill.



Interior view of a sugar mill.

organization which would represent them and work in their behalf in matters involving the various governments, in labor, and in agricultural matters.

This organization was chartered as the Planters' Labor and Supply Company.

The planters were divided into committees to study common problems and to report on such subjects as labor, possible crops for the Kingdom, the need for new roads and a harbor, legislation, sugar growing, forests, new or needed machinery, and even banking.

The Company published the Planters' Record, which kept the membership informed of events of interest to sugar growers and others interested in agriculture. Many of the articles concerned ways to improve agricultural production practices.

In 1892, a sugar chemist suggested that the industry should have its own experiment station. In 1895, the members of the Planters' Labor and Supply Company agreed, at their annual meeting, to support such a station. The next day, in a second meeting, the planters dissolved the Planters' Labor and Supply Company and formed the Hawaiian Sugar Planters' Association (HSPA).

In 1895, the HSPA hired a chemist and established a laboratory, an office, and a reading room in a building in downtown Honolulu. In 1896, the HSPA obtained some land in the Makiki area of Honolulu and planted experimental sugarcane on the land. In 1900, the experimental laboratory was moved to the Makiki area where the experimental crops were grown on eight acres of land. The City of Honolulu later expanded and tall apartment buildings ringed the Experiment Station and its experimental sugar fields. In 1974, the City bought the land for a park and HSPA erected a new building in Aiea.

The HSPA Experiment Station is known throughout the world for its

research in many scientific disciplines. Scientists working at HSPA have shown sugarcane planters in Hawaii many new ways to improve their operations.

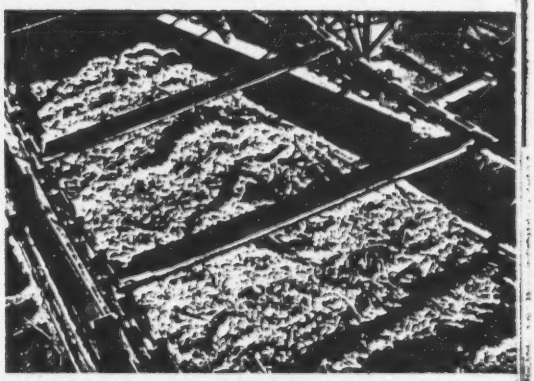
The HSPA researchers have invented numerous machines and techniques, and many of these techniques have been used in other agricultural operations. Its entomologists pioneered in the field of using natural enemies to control sugarcane pests.

One of the most important HSPA responsibilities is the breeding of improved varieties of sugarcane which produce more sugar and are resistant to drought and diseases. A number of sugarcane varieties must be available to growers in Hawaii because the climatic conditions vary in different parts of the State. A plantation in a generally cool and cloudy area with sufficient rainfall uses a different variety of sugarcane from that planted in warmer and drier areas.

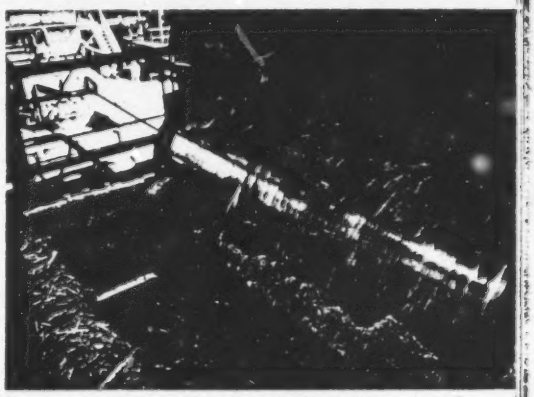
The Sugarcane

Sugarcane is a giant member of the grass family. Although it flowers under some conditions and produces true seed, it is propagated vegetatively by cuttings. Specially selected field areas are harvested for propagating material and the stalks are cut into sections of about two feet, each of which will have two or more buds, one at each node.

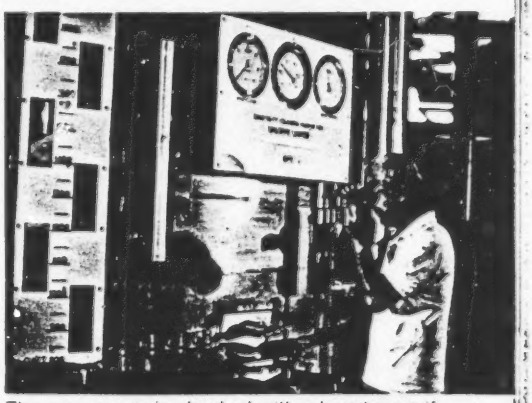
After the stalk pieces have been planted in the soil the buds will germinate to produce new cane plants. With warm temperature and plenty of moisture the young cane plants grow rapidly and can be 2 meters (6 ft.) tall within 4 months.



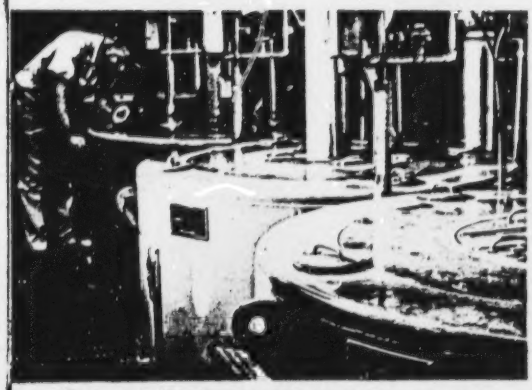
Shredded cane on its way into the mill where the sweet juices will be pressed from the fiber.



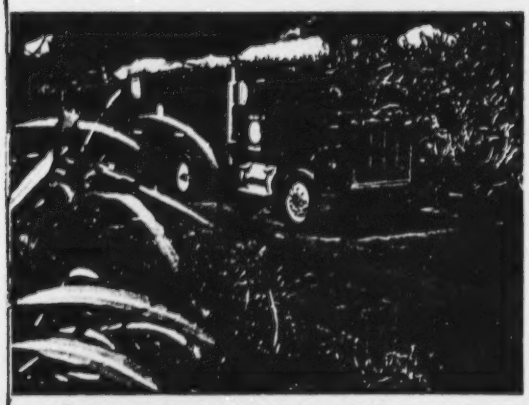
Prepared cane dropping into the first of a series of rollers in the mill.



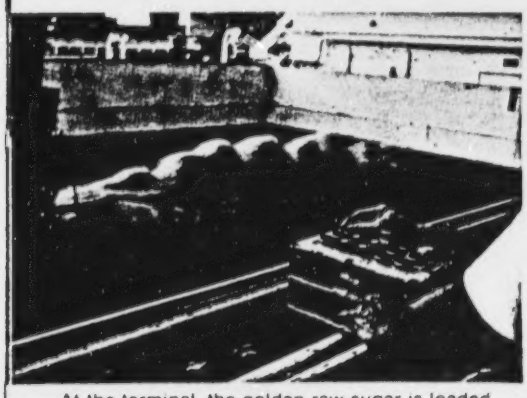
The massecuite is checked with a lens to see if crystals have formed.



Centrifugals spin molasses from the raw sugar crystals.



Trucks haul raw sugar to terminals.



At the terminal, the golden raw sugar is loaded onto ships.

As the sugarcane plant develops, new leaves are formed continuously by the growing point at the tip of the stem or stalk. Each leaf is attached to the stalk at a node and the leaf sheath protects the bud. As new leaves and nodes are formed, the stalk also grows by elongation of the internodes.

On the average, about three new leaves develop during each month and it is the young leaves at the top of the stalk that are active in producing sugar. Older leaves gradually become inactive, turn yellow, and may actually drop from the stalk. By the time the crop is ready for harvest, two years after planting, the stalk, where the cane plant stores sugar, may be up to 9 meters (30 ft.) long. Fields in Hawaii generally yield up to 225 tonnes per hectare (100 tons per acre).

All green plants convert radiant energy from the sun into carbohydrate energy and the sugarcane plant is one of the most efficient. This conversion process is called photosynthesis and takes place in the active leaves of the cane plant. A green substance in the leaf called chlorophyll enables the plant to use the sun's energy to combine water (H_2O) with carbon dioxide (CO_2) to form sugar ($C_{12}H_{22}O_{11}$). Soon after it is formed, sugar is transported from the leaf cells to the stalk where some of it is used for additional plant growth and some is stored. It is the stored sugar that is extracted from the stalk, refined and used for human food.

In the process of making sugar, the cane plant performs another service. It is a vital link in the carbon cycle, which is fundamental to human and other animal life on earth. The sugarcane plant removes

carbon dioxide from the air and returns to it pure oxygen which is breathed by man. It is estimated that over its two-year growing period, one hectare of sugarcane removes about 213 tonnes of carbon dioxide from the air and returns about 135 tonnes of oxygen (95 tons of carbon dioxide and 60 tons of oxygen per acre).

Most sugarcane in Hawaii is harvested two years after planting or ratooning. When a field is ready for harvest, workers set fire to selected portions. The quick, hot fire usually lasts only a few minutes and is the only practicable way of getting rid of the tons of trash that have accumulated while the crop is growing. Mature cane stalks contain about 70-75% water so they are not harmed by the heat of the fire.

Harvesting machinery is moved into the burned areas as soon as the fire is out. Sugarcane growers in Hawaii abandoned hand-cutting many years ago and now use a variety of mechanical methods. The one used most commonly is called a pushrake. This is a crawler tractor with large, strong tines mounted on the front. The pushrake cuts and breaks the cane stalks and at the same time pushes them into large windrows. Mobile cranes equipped with "grabs" load the cane from windrows into specially built trailer trucks which can haul 18 to 32 tonnes (20 to 35 tons) each trip from field to factory.

Another mechanical harvester is called a "V-cutter." This machine is also mounted on the front of a large crawler tractor and consists of a vertical power-driven knife, much like a circular saw, at the apex of a V-shaped blade. This harvester leaves rows of cut cane which a pick-up-transport accumulates and moves to

The Raw Sugar Factory
Powerful jets of water wash the cane as it enters the mill.
Chopped cane is crushed by a series of giant rollers to press out the sweet juice.
Lime is added and the juice is heated.
The juice mixture is sent to clarifiers where non-sugar particles settle out.
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the edge of the field for loading on trucks for the haul to the factory.

There is a constant search for new and better methods of harvesting cane mechanically. One now being developed cuts the cane stalk at its base, moves the stalks to a chopper blade which cuts them into short lengths, blows out some of the trash and then conveys the cane to a transport moving alongside the harvester.

Just as they built their own extensive irrigation systems, cane growers in Hawaii built and maintained the road systems over which most of the 10 million tons of harvested cane are trucked from field to factory.

The Raw Sugar Factory

When the cane arrives at the factory it is weighed and then unloaded from the trucks onto a large conveyor. This conveyor moves the cane at a steady rate to the cleaning plant where most of the remaining leafy trash, soil and rocks are removed.

Clean cane is then conveyed to a machine which chops and shreds it in preparation for the next process. This may be either "milling" or "diffusion."

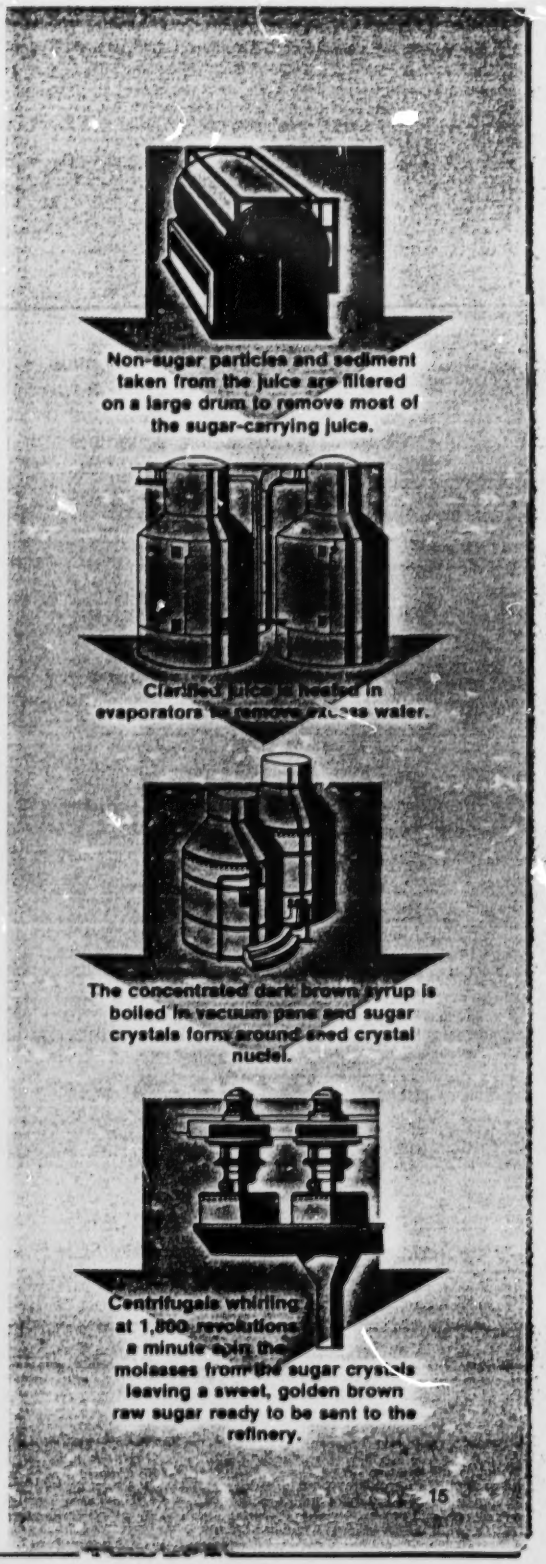
Most factories use a mill, consisting of a train of several large, heavy, grooved rollers driven by steam engines or turbines. Each set of rolls draws the mat of prepared cane through and squeezes it to express the juice. Much juice is extracted by the first set of mill rolls and, as the cane progresses, the pressure on succeeding mills is increased to press out as much juice

as possible. Water is added to the cane mat as it passes through the mill to aid in the extraction. Sugar stored in the cane stalks is in solution and thus the more plant juice that can be expressed from the stalks, the higher the recovery of sugar.

In factories using the diffusion process, shredding is more thorough than for a mill and the prepared cane is moved slowly through a large tank. Hot water is added and the constantly circulating water-juice mixture soaks the sugar from the cane fibers. Juice is steadily drawn off during the process and as the wet fiber leaves the tank it is pressed to complete the extraction.

Following either milling or diffusion, juice separated from cane fiber is pumped to a part of the factory called the boiling house. The cane fiber, called "bagasse," is conveyed to the factory's boiler where it is burned to generate steam. Bagasse fuel provides the energy to make enough steam for the boiling house processes, to drive the turbines which power the mills, and to drive the generators which make electricity. Enough electricity is available to power all the motors in the factory, to pump irrigation water and, in some cases, to feed into the public power grid.

In a time of energy shortage, it is important that sugar producers obtain all of their fuel for factory operations from a part of their crop and can even contribute toward meeting some of the need for electricity for other uses. There are possibilities of recovering additional energy in other forms—such as alcohol—from the sugarcane crop and the feasibility of these are being studied by Hawaiian producers.



Non-sugar particles and sediment taken from the juice are filtered on a large drum to remove most of the sugar-carrying juice.

Clarified juice is heated in evaporators to remove excess water.

The concentrated dark brown syrup is boiled in vacuum pans and sugar crystals form around seed crystal nuclei.

Centrifugals whirling at 1,800 revolutions a minute spin the molasses from the sugar crystals leaving a sweet, golden brown raw sugar ready to be sent to the refinery.

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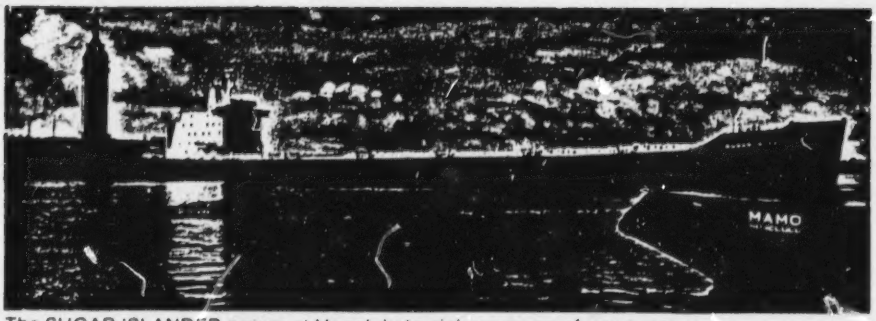


The SUGAR ISLANDER arrives at Honolulu to pick up cargo of raw sugar.

Inside the boiling house, the juice is tested and lime is added. The raw juice is then heated and sent to a large settling tank called a clarifier where some of the impurities present settle out. The clear juice is drawn off and sent through evaporators which carry off the excess moisture in the form of steam. This leaves a thick, dark syrup.

The syrup is then transferred to vacuum pans where it is boiled and tiny "seed crystals" are added. These seed crystals act as the nuclei around which larger sugar crystals form.

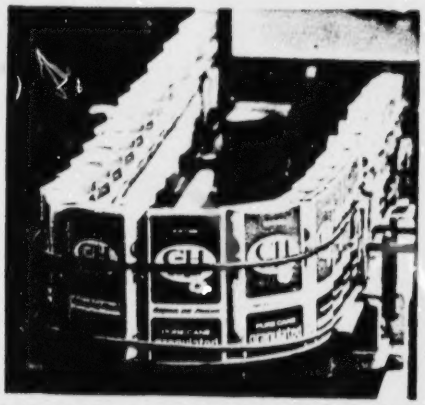
When the crystals have formed, the vacuum is broken and the heavy, dark mixture, called massecuite, is transferred to centrifugals. The centrifugals, which rotate at the rate of up to 2,200 revolutions per minute, spin the liquid molasses from the sugar crystals. The growing of further crystals from this molasses is repeated until no more can be grown. Most of the remaining "final" molasses is shipped to the Mainland where it is used as livestock feed; some is fed to cattle in Hawaii.

The main product is golden brown raw sugar ready to be shipped to the California and Hawaiian Sugar Company refinery in Crockett, California.

Refined sugar is turned out in a variety of products—from the familiar white crystals for home cooking, canning and table use, to powdered sugar for bakers, to liquid sugar for commercial canners and soft-drink manufacturers, to brown sugar for special uses at home and in industry.

In addition to the large refinery at Crockett, the sugar producers in Hawaii also own cooperatively a small refinery at Aiea on Oahu which refines sugar for use in the Islands.

Many people remember, when they see the brightly colored C and H bags and cartons, that the sugar inside is a product of the sunshine and water in the State of Hawaii.



At Crockett, the sugar is refined and packaged.

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As a tribute to the thousands of men and women in the sugar industry of Hawaii.

MAHALO
(The Hawaiian Word For "Thanks")